# AN INVERTED SIPHON IN A SUCTION LINE[1]

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A feature of water works construction which presents elements of great concern to the designing engineer is the so-called suction line leading from the source of water supply to the pumping machinery. A statement of the natural phenomena responsible for the performance of liquids under these circumstances will be pertinent.

When a piston traverses the course of its component cylinder, whatever substance occupies the body of the cylinder must needs be displaced, and as the channel provided for its movement is usually that circumscribed by the pipe leading from the cylinder, there is no limit to which the fluid may be forced other than that set by the strength of the pipe to withstand the pressure and the power supplied behind the piston to deliver it. On the other hand, in all cases where the pump cylinder is at a higher elevation than the source of supply, there is a determinate limit to which any liquid will rise to fill the space vacated by the piston in its forward movement. The temperature of the liquid in a measure affects the operation of pumps, but inasmuch as the cases occurring in water works operation have to do with water only, and at temperatures varying only from 33° to 70°, this feature may be neglected.

The height to which water will rise to fill a chamber vacated by a piston is directly proportional to the pressure of the air, which in turn varies with the elevation of the station above sea level, being greatest at sea level and reducing gradually with the height. In terms most used by the engineer these relations are expressed in inches on the mercury barometer or in feet on the water barometer, a fixed ratio existing between the two. At sea level we have 30 inches mercury and 34 feet water pressure; at an elevation of 1000 feet, 28.94 inches mercury and 33.3 feet water; at 2000 feet elevation, 27.92 inches mercury and 31.6 feet water; at 10,000 feet ele-

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vation 20.93 inches mercury and 23.7 feet water. For practical consideration in the central states we can use the figures 28 inches mercury and 32 feet water. It is evident therefore that under no possible circumstances can a pump operate at a greater height than 32 feet above the water level, inasmuch as this is the height to which the air pressure will force water to rise under perfect conditions of vacuum.

There are other features entering into the problem which must be considered, all of which tend to reduce this height, viz: Loss of head due to friction of water flowing in pipes; entrance of air to the suction line through defects in material of which the pipe line is constructed and through defective joints; elements of reactionary forces due to the reciprocating motions of the pump plungers, and in a measure not thoroughly comprehended yet often neglected, the presence of entrained air or other gases found in water percolating through sand beds or filter galleries. This last feature often gives rise to much difficulty in operating pumping machinery and is not usually developed until after the plant is in operation, requiring expensive alterations or additional equipment to correct the difficulty.

Loss of head may be be considered and accounted for as in ordinary cases of water flowing through pipes, a corresponding reduction in height being made. For defects in pipe material and leaky joints the remedy is obvious, viz.: replacement and repair. Under no circumstances should a suction line be covered until by thorough test these defects have been developed and corrected. Water hammer and column reactions can be controlled by the proper regulation and operation of the pumps. Entrained air and gases may be collected in suitably arranged chambers above the suction line at intervals and relieved by adequate vacuum pumps.

The prime requisite in any suction line is that it should have a continuously ascending grade from the water source to the pump chamber. It sometimes occurs, however, by reason of the location of the pumping station with relation to the collecting system that this condition becomes impossible of fulfillment, and recourse must be had to other methods of accomplishing the same result.

A method becomes available in a form of an inverted siphon with proper equipment for removing collected air or gases from the high point in the siphon. To illustrate by a case in point we will briefly describe the installation of the inverted siphon in the collecting system of the Boone City water works, which was designed

and installed by the writer at Boone, Iowa, in the spring of 1911.

Two distinct systems of screened wells connected to cast iron suction mains were installed. One system followed the east bank of the Des Moines River for a distance of approximately 2000 feet, the wells being located in water-bearing sand and gravel and connected to an 18-inch cast iron main laid at a uniform grade of 0.1 per cent, beginning at an elevation of 2 feet above low water and terminating at the common header of both lines, at an elevation of 4 feet above low water. This header, together with the low-lift pumps, is located in a concrete pit approximately 24 feet in depth, and 300 feet from the river bank.

The second system, and the one in which we are more interested, is located in an island in the river, which it traverses for a distance of 800 feet. Wells similar to these on the land system are connected to the pipe line, all being equipped with hermetically sealed concrete manholes as a measure of protection during stages of high water. The open channel between the island and the mainland is 200 feet in width, the bottom being approximately 12 feet below the general level of the island.

The cast iron suction main was laid on a uniform grade beginning at an elevation of 1.60 feet above low water and ascending through a distance of 800 feet to a point opposite the water works station, to an elevation of 2.40 feet above low water. The distance from this point to the pump pit in the station is approximately 550 feet. An air chamber was provided by capping an 18 by 18 by 18-inch cast-iron tee, and dropping the main vertically to an elbow connection with the inverted siphon pipe under the east channel of the river. This pipe was laid to a carefully adjusted vertical curve to conform as much as possible with the general form of the river bottom.

A 2-inch galvanized iron pipe leading from the top of the air chamber and carried down and parallel with the siphon pipe crosses the channel and is connected to a wet vacuum pump in the pit building. The siphon and air pipe were banded together and carefully lowered to place from a pile trestle bridge, and bedded 4 feet below the channel bottom. Flash boards attached to the top of the pipe during the process of lowering forced the water in the stream under the pipe, eroding sand and gravel from below and materially expediting the operation of excavation for the pipe bed.

At low water stages the system at times operates under 16 to

18 inches vacuum, corresponding to approximately 20 feet hydraulic suction.

The plant has been in operation for five years and to date no trouble attributable to this feature of the installation has been experienced.